INTRODUCTION

This study develops an updated stratigraphic framework of the Late Campanian Neslen Formation and equivalent strata of the Mount Garfield Formation based on process-oriented facies analysis and interpreted depositional environments. These strata are exposed along 150 km of the Book Cliffs area in eastern Utah and western Colorado. The coal-bearing interval is best developed between the Colorado River to the east and the Green River to the west (fig. 1). To the east, the coals pinch out against nearshore marine sandstones of the Mount Garfield Formation, and west of the Green River, the main part of the coal-bearing Neslen changes facies into alluvial deposits of the Late Campanian Castlegate Sandstone (Lawton, 1986). The age of the Neslen Formation and equivalent strata of the Mount Garfield Formation is constrained within the Campanian by the occurrence of *Baculites scotti* within the Upper Sego Sandstone in the eastern Book Cliffs (Gill and Hail, 1975) and the occurrence of Didymoceras cheyennense in strata above the Rollins (Trout Creek) Sandstone in the Grand Hogback area (Madden, 1989).

Coals in the Neslen and Mount Garfield Formations have been of interest since the turn of the 20th century because of their potential for exploitation. This is not true today as there are no active mines from the Neslen, but interest in the unit continues because of its potential for coal bed methane primarily in the Sego Canyon area in the western part of the study area (fig. 1). The Neslen is also worthy of study due to the excellent exposures of the unit along the Book Cliffs and such a study allows the opportunity to develop coal depositional

STRATIGRAPHIC NOMENCLATURE

The main part of the study interval encompasses the Neslen Formation and equivalent parts of the Mount Garfield Formation. Other formations discussed in this report are the Anchor Mine Tongue of the Mancos Shale, the Sego Sandstone, and the Bluecastle Tongue of the Castlegate Sandstone. The main focus is on coalbearing strata of the Neslen Formation and its stratigraphic equivalents in the Mount Garfield Formation. The coal-bearing Neslen Formation changes names at the Utah/Colorado state line into undifferentiated Mount Garfield Formation. The coal bearing facies can be traced into the Grand Junction area where it pinches out between marine deposits of the Sego Sandstone and Mount Garfield Formations, which include the upper Sego, Corcoran, Cozzette, and Rollins Sandstones, and offshore and marine deposits of the Mancos Shale. The main coal zones are in ascending stratigraphic order: Anchor, Palisade, Chesterfield, and Cameo. Summaries of the stratigraphic nomenclature are discussed by Young (1955, 1983) and by Franczyk (1989). In this report we tie our discussions into the existing stratigraphic nomenclature when possible, but discuss individual units in terms of stratigraphic position within our measured sections to avoid further confusion

METHODS

concerning stratigraphic nomenclature. New information that has a bearing on the stratigraphic units is presented

Twenty three sections were measured during this study with varying degrees of detail. Sections were concentrated in the Floy Canyon area and in the Colorado portion of the Book Cliffs (Fig. 1). In Floy Canyon there are three complete sections and two partial sections (see Fig. 3) that are based on detailed lithofacies. In the eastern study area, complete detailed sections were measured at the Book Cliffs Mine, the Grasso Mine, Hunter Canyon, Coal Gulch, and East Salt Wash (Fig. 4); numerous partial sections were also measured in areas of complexity; and three complete but less detailed sections were measured at Mack Wash, Layton Wash and Ruby Lee Reservoir. Between the two main study areas, we measured detailed sections at San Arroyo Canyon and Buck Canyon and sketched numerous sections across the Book Cliffs visiting most of the easily accessible canyons. Two pre-existing measured sections were used and were walked through in order to add additional facies interpretations and paleocurrent information: these were at Tusher Canyon (Lawton, 1983) and the Farmers Mine section near Palisade, Colorado (Gill and Hail, 1975) (Fig. 2).

FACIES ANALYSIS

Lithofacies identified on outcrop from the Neslen Formation and equivalent strata in the Mount Garfield Formation are grouped into four general depositional environments composed of eight facies that were deposited in: coastal plain, estuarine complexes, and shoreface, and offshore. A fifth depositional facies, alluvial plain, is recognized from the Bluecastle Tongue of the Castlegate Sandstone in the western part of the study area. Depositional settings are identified by background color patterns on Figures 2, 3, and 4. Column colors show interpreted relative salinity including freshwater, brackish water, and normal marine on Figures 2 and 4.

Neslen Formation/Mount Garfield Formation (part)

Coastal Plain Deposits (light green background color) Coastal plain deposits are defined in this report as rocks that accumulated in freshwater (green column color) and brackish water (light blue column color) environments adjacent to a paleo-shoreline. Coastal plain deposits are dominated by organic rich facies, lenticular to tabular sandstones, and inclined heterolithic strata. The coastal plain deposits are transitional into estuarine complexes.

Organic rich facies (Interpretation: Mire/marsh)

in a following section on stratigraphic discussion.

Description.— This facies consists of coal, carbonaceous shale, and organic rich mudrock. Coal makes up about 1-4% of the stratigraphic section, is dull to bright with a banded appearance, and is highly resinous. Carbonaceous shale in our usage is highly fissile and organic rich and comprises as much as 13% of the stratigraphic section, for example at Floy Canyon. Organic rich mudrock contains disseminated plant material and/or roots and contributes as much as 12% of the total section (Floy Canyon). Original lamination has been destroyed in about 2/3 of the organic rich mudrock in the study interval. Post-depositional structures include roots, burrows, slickensides, and deformed bedding. The organic rich mudrock, and in a few cases carbonaceous shales,

contain gastropods, bivalves, leaves, Teredolites, and dinosaur bones. Interpretation.— Coal, carbonaceous shale, and organic rich mudrock are interpreted to represent the deposits of wetlands - mires, marshes, and salt marshes. Bivalves, gastropods, and Teredolites within some mudrock suggest a transition between freshwater and brackish water influence. This is supported by Fisher and others (1960) who found both freshwater and brackish water fossils within the Neslen in Utah. Randomly oriented slickensides are attributable to expanding clays and indicate the presence of paleosols (Mack and others, 1993). This facies assemblage makes up a large proportion of the original sediment deposited in the study interval considering the high compaction ratio of the organic matter that followed burial.

Lenticular to tabular sandstones and inclined heterolithic strata (Interpretation: Fluvial and tidallyinfluenced channel)

Description.—This facies is composed of cross-stratified sandstone, cross-laminated sandstone, and cross-laminated to bioturbated heterolithic strata. This complex facies assemblage can be found within successions that grade laterally from lenticular to tabular geometries. Lenticular deposits have overall fining upward grain sizes, are up to 8 m thick, and typically average 3-4 m thick (Fig. 3). Individual channelized deposits are estimated to be typically less than 100 m wide and are composed of cross-stratified sandstone and inclined heterolithic strata. Tabular units coarsen upward from mudrock into sandstone and are up to 5 m thick. Tabular units are dominated by cross lamination, and wavy and lenticular lamination in an overall heterolithic package that frequently has burrows or may be bioturbated.

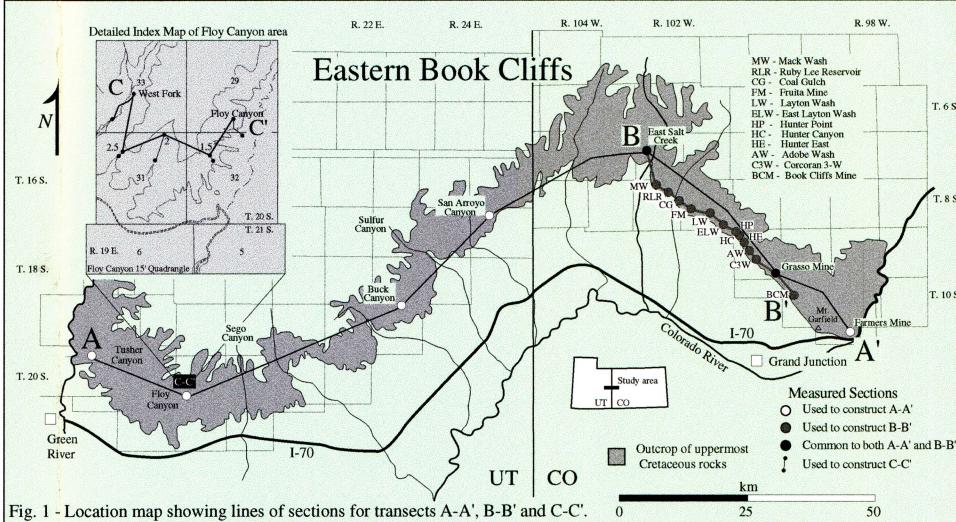
Cross-stratified sandstones contain both trough and planar tabular beds, abundant mud clasts, and

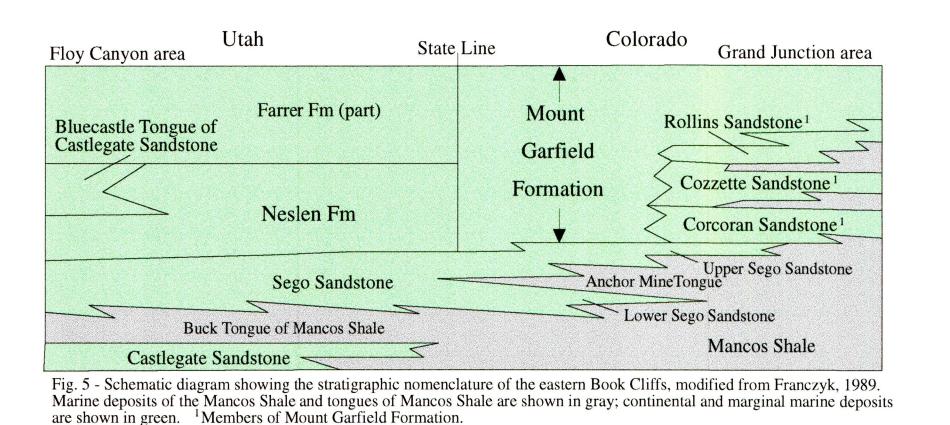
Teredolites-bored logs; reactivation surfaces in cross-stratified sandstones and burrows are fairly common; and sigmoidal shaped beds have been observed. Inclined heterolithic strata constitute as much as 11% of a stratigraphic section and consist of couplets of cross-laminated sandstone and mudstone that frequently are separated by straight-crested symmetrical ripples. All units have abundant Teredolites, and a fairly diverse assemblage of trace fossils, that include Rhizocorallium, Teichichnus, Bergaueria, and Pelecypodichnus. Interpretation.— Lenticular deposits of this facies are interpreted as fluvial channels (light green column color) or tidally influenced channels (purple column color). Tabular deposits are interpreted as bayhead deltas or crevasse splays (light green column color). The lenticular deposits show gradations in amount of cross bedding, ratio of sand to mud, and degree of burrowing depending on their location within the depositional system. Higher energy deposits contain abundant cross-stratified sandstone, low amounts of mud, and sparse burrows; a middle energy range is dominated by cross-laminated sandstone, inclined heterolithic strata, and common burrows; the lowest energy deposits are heavily burrowed but some beds still retain relict inclined heterolithic strata and crosslaminated sandstone. Lenticular sandstone deposits represent high-energy channel fills associated with small bayhead deltas. Bayhead deltas produce coarsening upward successions at their terminus capped by tabular sandstones. Tabular units also show a gradation from higher-energy deposits dominated by cross lamination to low energy units dominated by burrowing. Lenticular heterolithic deposits represent abandonment fills of high

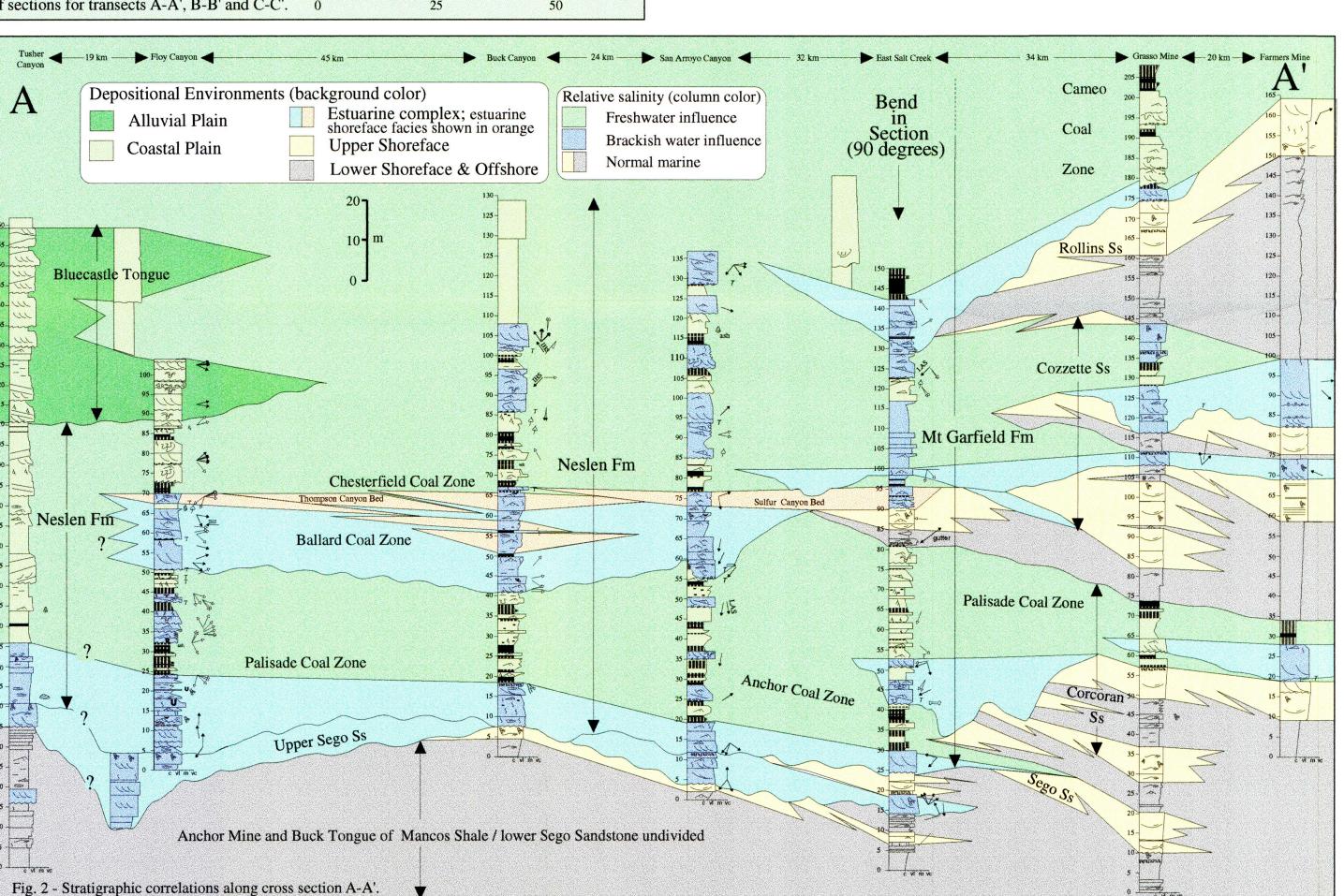
Estuarine complexes (light blue background color)

Estuarine complexes are dominantly brackish water deposits that overlie a basal erosion surface. The erosion surface typically can be traced for one or more kilometers and cuts into and across various facies. In their most landward exposures and locally within the complexes, brackish water deposits grade into coastal plain deposits. At their more seaward localities, the erosion surfaces are observed to cut into stacked shoreface deposits. The basal erosion surfaces are overlain by rocks that display features that indicate tidal and brackish water influence and contain amalgamated channels that have features that suggest deposition within a tidal environment. These tidal deposits are usually in contact with strata that accumulated in deeper water marine environments. The superposition of estuarine strata over deeper water marine deposits is interpreted to represent a facies dislocation. Each dislocation represents a basinward shift in facies over a scoured surface cut during a relative fall

energy channels or secondary channels that received mixed fluvial and tidal input.







in base level. The amalgamated nature of the deposits further suggests deposition within an incised valley rather than within a single tidal inlet or tidal channel. Distinguishing features within these estuarine complexes include compound cross-stratification, symmetrical and flaser/wavy/lenticular cross laminated sandstone, and mudrock.

Compound cross-stratification (Interpretation: Tidal channel and sand flat)

Description.— The tidal channel and sand flat facies consists primarily of cross-stratified sandstone. Cross stratification set boundaries are separated from each other by cross laminated sandstone and siltstone or carbonaceous drapes. Also included in this facies assemblage is cross-laminated and bioturbated sandstone and lenticular and flaser-bedded sandstone. Oysters, Ophiomorpha, and Teredolites are commonly associated with these sandstones. The facies is restricted to the Upper Sego Sandstone, the lower part of the Neslen (Fig. 3), and the Mount Garfield Formation. Units are erosionally based and their geometries are lenticular or sheetlike. Mud chips and intraformational lags are common.

Interpretation.—The presence of Teredolites and oysters (Ostrea glabra Fisher and others, 1960) indicates a brackish water environment for this facies assemblage. Ophiomorpha found in the lower Neslen Formation and Upper Sego Sandstone may indicate marine influence. The facies is usually found in proximity to shoreface deposits and therefore must have been deposited close to open marine waters. The cross-laminated units that separate sets of cross stratification, the reactivation surfaces within the crossbeds, and the mud preserved within cross laminated sets between cross-stratified beds all strongly suggest fluctuating flow velocities that are consistent with tidal currents. Double mud couplets and lenticular rippled beds that cap cross-stratified beds and rare double mud drapes within cross stratification indicate a subtidal environment for deposition. Flattened symmetrical wave ripples are suggestive of emergence related to deposition within an intertidal zone. This facies is interpreted to represent tidal channel, tidal bar, and sand flats of open estuaries.

Symmetrical and flaser/wavy/lenticular cross laminated sandstone (Interpretation: Estuarine shoreface) Description.— This facies consists of continuous sandstones that can be traced over tens of kilometers (see Fisher, 1936, Thompson Canyon/Sulfur Canyon Beds). The primary sedimentary structures are symmetrical cross lamination and wavy/lenticular cross lamination. Burrows or *Teredolites* are common and the sandstone can be bioturbated. The sandstones are present in the upper part of overall coarsening upward successions grading up from mudrock. Cross stratification, horizontal lamination, or small-scale hummocky cross stratification are rare. The most striking feature of the sandstones is the clean well sorted sand; the high quartz percent-

age (~ 100%) gives the sands an overall white appearance. The units change laterally into carbonaceous mudrock Interpretation.—The presence of Teredolites and burrows suggests a brackish water environment for

deposition of these sandstones. The abundance of wave generated symmetrical ripples indicates more wave influence than tidal influence, and this is further supported by the clean winnowed nature of the sands. Finally the continuous nature and association with mudrock, interpreted as marsh and bayhead deltaic deposits, and dominance of cross lamination suggests a low energy shoreface/sand flat and estuarine beach for the depositional environment of these sandstones.

Mudrock (Interpretation: Open estuarine)

Description.—This facies consists of laminated or bioturbated mudrock, and streaky to lenticular-bedded shales. The facies is gradational with the tidal channel and estuarine beach facies assemblages due to the gradation of lenticular bedded sandstones with wavy bedded sandstone. Plant fragments are common. Rare preserved bivalves including *Corbula* sp. are present and one limpet was found. This facies is relatively rare in the study interval but is most common in the Cozzette Sandstone, for example at the 65m level in the Layton Wash section (Fig. 4).

Interpretation.—The abundant trace fossils and rare brackish water bivalves indicate a brackish water environment for deposition of the facies assemblage. The predominance of mud indicates quiet water deposition and the association of the facies with tidal and low-energy shorefaces suggests an estuarine or lagoonal origin for

Upper Shoreface deposits (yellow background color) and Lower Shoreface and Offshore deposits (gray background color)

Shoreface deposits are recognized by their coarsening upward grain size and their extensive lateral continuity. Upper shoreface deposits consists predominantly of thick cross stratified sandstone whereas lower shoreface/offshore deposits consist predominantly of mudrock with interbedded thin sandstones. Lower shoreface and offshore deposits are transitional into upper shoreface deposits.

Cross-stratified and planar-laminated sandstone (Interpretation: Upper shoreface) Description.—This facies assemblage consists of coarsening upward successions of very fine to medium grained, well-sorted sandstone. Sedimentary structures include amalgamated hummocky cross stratification, swaley cross stratification, trough or planar tabular cross stratification, and sub-horizontal lamination; some beds contain burrows, notably *Ophiomorpha* or *Thalassinoides*, or can be bioturbated. Swaley cross stratification is volumetrically the most common sedimentary structure while trough and planar tabular cross stratification and sub-horizontal lamination are minor components. Swaley beds are frequently scoured by the tidal facies assem-

Interpretation.—This facies succession is interpreted as shoreface deposits based on the coarsening upward grain size, an upward increase in flow strength indicated by the sedimentary structures, and by the presence of swaley cross stratification and hummocky cross stratification, which are indicative of storm generated structures typically found in nearshore marine settings (Dott and Bourgeois, 1982; Leckie and Walker,

Interbedded sandstones and mudrock (Interpretation: Lower shoreface to offshore marine transition) Description.—This facies consists of interbedded sandstone and mudrock. Sedimentary structures in sandstones include symmetrical cross lamination, horizontal lamination and isolated hummocky cross stratification. These deposits are juxtaposed against or laterally gradational into amalgamated hummocky cross stratification or swaley cross stratification. Burrows and bioturbation are common within this facies *Interpretation.*—The facies represents deposition in an area transitional from shoreface to offshore based on the presence of marine fossils (Gill and Hail, 1975) and its association with hummocky and swaley cross

Bluecastle Tongue of the Castlegate Sandstone (part) Alluvial Plain Deposits (dark green background color) Alluvial plain deposits as defined in this report include strata deposited within and adjacent to river

stratification. Most of the sediments were deposited below storm wave base with the exception of the isolated

hummocky cross stratification which was formed by reworking during storms.

systems located landward of the coastal plain.

Medium- to coarse-grained crossbedded sandstone (Interpretation: Fluvial channel) Description.—This facies consists of primarily trough and planar tabular cross-stratified sandstone and minor amounts of cross laminated and convoluted sandstone, intraformational lags, inclined heterolithic strata, and mudrock. The deposits generally consist of fining upward successions and show an upward decrease in the flow strength of sedimentary structures. The facies assemblage consists entirely of the Bluecastle Tongue of the Castlegate Sandstone. The sandstone is distinctive because it contains the first coarse grained sand above the Buck Tongue of the Mancos Shale and is restricted to the western part of the study area. Interpretation.—These deposits are interpreted as channel deposits based on their overall upward reduction in flow strength. The absence of burrowing, the lack of *Teredolites*, which is extremely abundant in the

Neslen, and the lack of mudstone drapes suggest that fluvial rather than tidally influenced processes produced

STRATIGRAPHIC DISCUSSION

The main study interval includes the Neslen and Mount Garfield Formations, which are time-equivalent units that change names at the Utah-Colorado state line. The coal-bearing parts of the Neslen Formation and Mount Garfield Formation change facies into shoreface sandstones of the Mount Garfield Formation and marine shales of the Mancos Shale in the eastern part of the study area (Fig. 2). The relationship of these two formations with the underlying Sego Sandstone is complex and has been the cause of much confusion. This section discusses stratigraphic problems of units in the study interval.

Sego Sandstone

The Sego Sandstone has traditionally been divided into lower and upper nearshore marine units separated by the Anchor Mine Tongue of the Mancos Shale (Erdmann, 1934; Young, 1955) (Fig. 5). Recent sequence stratigraphic studies by Van Wagoner and others (1990) and Van Wagoner (1991) demonstrate that the Sego consists of nine high frequency sequences and that a significant portion of the Sego sandstones was deposited in an estuarine environment rather than a shoreface setting. There is still some confusion about the maximum seaward extent of the upper Sego Sandstone. Erdmann (1934) and Fisher and others (1960) show the unit extending south of the Colorado River while Young (1955, 1983) and Gill and Hail (1975) show it pinching out near Mount Garfield, a few kilometers west of the Farmers Mine section (Fig. 1). Van Wagoner (1991) considered the upper Sego to be mostly an estuarine sandstone and they describe the estuarine facies as changing into coastal plain deposits from East Salt Creek to the southeast to Coal Gulch. We also noticed a similar arrangement for an estuarine unit (15 m level East Salt Creek section, Figs. 2 and 4) showing it pinching out between East Salt Creek and Mack Wash (Fig. 4), but we did not physically trace it out. The complex arrangement of shoreface deposits at the top of the Mancos Shale in this area makes it hard (or maybe impossible) to distinguish Sego shoreface sandstones from overlying Corcoran sandstones of the Mount Garfield Formation.

Neslen Formation

The Neslen Formation was named for coal-bearing strata above the Sego Sandstone and where present below the Bluecastle Tongue of the Castlegate Sandstone (Fisher and others, 1960). Based on our correlations, the Neslen is equivalent to all the coal bearing section below the Cameo coal zone in the Mount Garfield Formation. Based on a review of the work of Fisher (1936) it is apparent that the contact with the Sego Sandstone was placed at the break in slope between cliff-forming sandstone of the Sego and slope forming sandstone and mudrock of coal bearing strata of the Neslen. Unfortunately, this is not a good criterion, because unlike other Cretaceous nearshore marine sandstones that show good coarsening upward successions, the Sego consists primarily of estuarine sandstones and heterolithic strata. Tidal deposits of the Neslen can cut many meters into tidal deposits of the Sego (Van Wagoner, 1991) making this contact difficult to determine without detailed studies over the whole of the central Book Cliffs.

Palisade Coal Zone

This is the lowest coal zone in the Neslen Formation and was mapped with confidence from the Colorado/Utah state line into the Floy Canyon area by Fisher (1936). Based on information he received from Erdmann (1934), Fisher mistakenly called this coal zone the Palisade instead of the Anchor as pointed out by Young (1955). This coal zone in the Neslen splits into numerous seams and attains a maximum thickness of about 1.5 m (Fisher, 1936). The coal zone can contain a prominent altered volcanic ash, which was noted in several sections in Floy Canyon area and in other sections to the east, such as Sego Canyon.

Ballard Coal Zone

The Ballard coal zone was named by Fisher (1936) for a persistent zone of coal just below the Thompson Canyon sandstone bed. It was mapped over a distance of about 50 km by Fisher (1936) from Floy Canyon to Buck Canyon and later the name was extended to several lenticular occurrences of coal in the same stratigraphic level for another 25 km to the east near the Utah/Colorado state line by Gualtieri (1991a, 1991b). This zone is at the same approximate stratigraphic position as the Palisade coal zone of Erdmann (1934) in Colorado (Fig. 2) and, based on our study, is most likely the same zone.

Thompson and Sulfur Canyon Beds

The Thompson Canyon and Sulfur Canyon Beds were named for relatively continuous sandstone beds that can be traced for kilometers on outcrop (Fig. 2) and share rather distinctive features (see Facies Analysis, symmetrical and flaser/wavy/lenticular cross laminated sandstone). In addition to their continuity, the sandstones are dominated by wavy/lenticular bedding and symmetrical wave ripples, often are burrowed to bioturbated including Ophiomorpha (see Franczyk, 1989, her plate 2, Sego Canyon section), and contain hummocky cross stratification at some localities. The most striking feature of the sandstones is the clean well sorted quartz sand that makes up the beds. The beds have been traced into tidally influenced channels, for example in the Buck Canyon area, and into carbonaceous shale in the Floy Canyon area (our Fig. 3, between sections West Fork and Canyon #2). We interpret the sandstones as estuarine beach and sand flat deposits that formed marginal to

There has been some debate about the continuity and correlation of these beds. Fisher (1936, p. 18) thought they were two continuous beds equivalent to the Rollins Sandstone. Others thought they were the same bed (Gualteri, 1991a), which would make them continuous for almost 100 km! Erdmann (1934) did not mention the beds at all. In this study we were able to correlate the Sulfur Canyon Bed to the same stratigraphic level as the Cozzette Sandstone between the Utah/Colorado State line and East Salt Creek (Fig. 2). There is still some uncertainty about the details of the relationship between the two units, because we were not able to walk them out the whole way. It is also apparent that at any one locality, there are several beds that are candidates for the Thompson Canyon Bed. At Strychnine Wash there are three continuous beds that could be candidates. At Buck Canyon, Fisher (1936) showed the Thompson Canyon Bed pinching out to the east and the Sulfur Canyon pinching to the west. In a detailed examination of the beds at Buck Canyon (Fisher, 1936, plate 7, section 232), we found the Thompson Canyon Bed being replaced laterally by a 8 m thick tidal channel complex, which we believe represents an estuarine fill based on its complex fill and sheetlike geometry. The Sulfur Canyon Bed consists of at least four thin coarsening upward successions that are finally capped by a coal. In tracing out the top bed, a fifth coarsening succession appeared above the coal, suggesting a shingling of the sandstones to the east. The lowest coarsening succession tends to be enclosed in mudrock suggesting a landward shift in facies; whereas the upper several successions appear to be small scale foreward stepping shoreface successions. We interpret the successions to be backward and forward stepping estuarine beaches/tidal flats and thus the Thompson Canyon and Sulfur Canyon Beds are probably not the same sandstone and the overall geometry is complex.

A detailed study from Buck Canyon to Sulfur Canyon would probably be the best place to develop an understand-

Chesterfield Coal Zone

ing of the internal geometry of these sandstones.

The Chesterfield coal zone is one of the most extensive coal zones in the Neslen and is traceable for about 120 km along the Book Cliffs from a few kilometers east of Tusher Canvon in Utah (Fisher, 1936) to near East Salt Creek in Colorado (Figs. 1 and 2). The Chesterfield maintains a fairly consistent interval thickness of about 3 m thick with 1 or 2 seams on top of the Thompson Canyon bed in the western part of the study (Fig. 3), but becomes a highly diffuse zone with numerous seams in an interval as much as 25 m thick at Buck Canyon (Fig. 2; Fisher, 1936, plate 7, section 232-234).

Mount Garfield Formation

This is the lowest coal zone in the Mount Garfield Formation (Fig. 2). As noted by Young (1955), the Anchor does not sit within the Mancos Shale as thought by Erdmann (1934), because the coal in question and underlying carbonaceous shale rests on about 5 m of wavy/lenticular bedded heterolithic strata that subtly cuts out hummocky cross stratified beds (see Erdmann's photo on plate 7B and our Coal Gulch section Fig. 4). The Anchor Coal of the eastern study area corresponds to the Palisade coal of the western study area.

Corcoran Sandstone

sion of "White Pioneer" sandstone).

areas of complex scour and fill by tidal deposits.

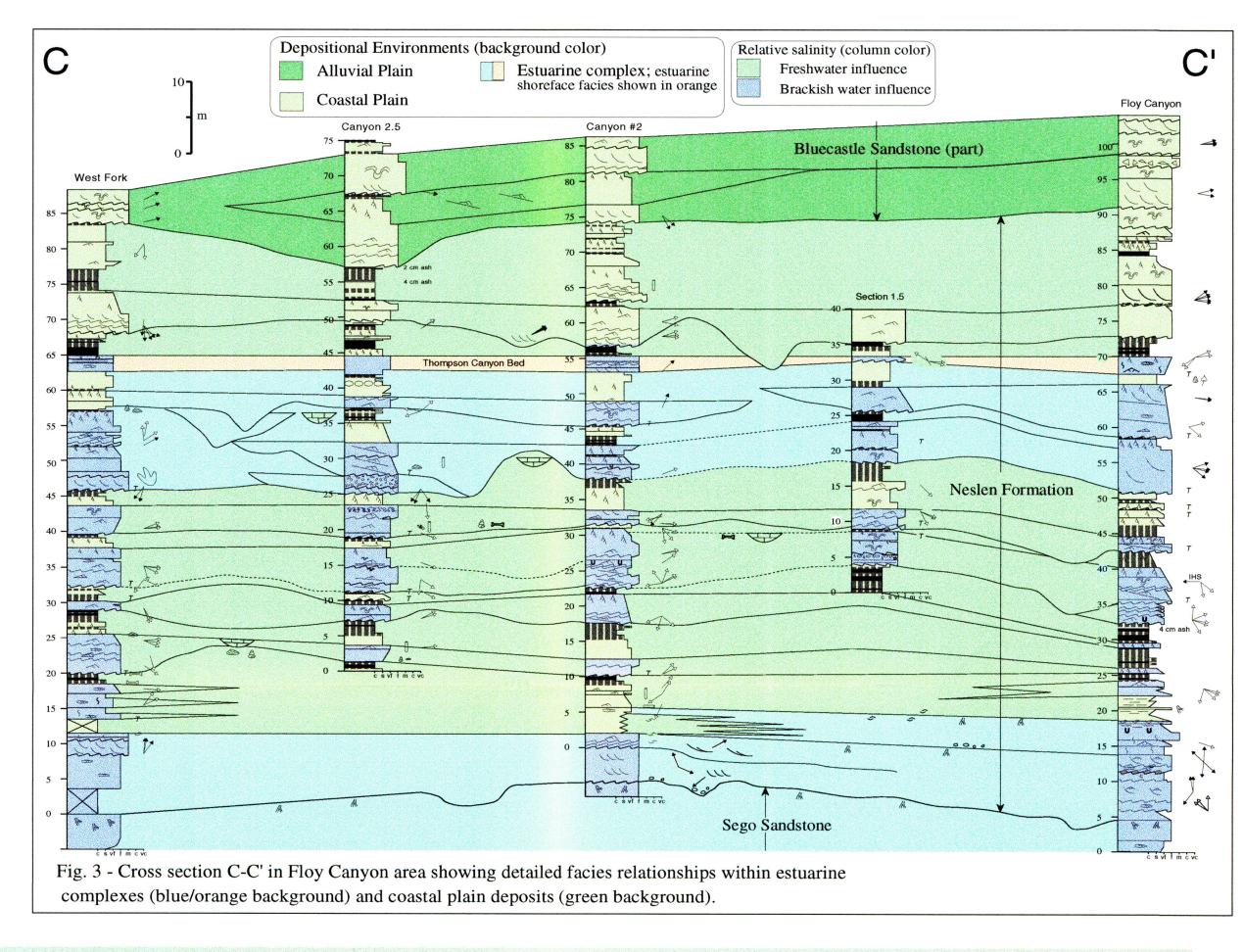
Rollins and Cameo may be in two separate sequences.

Anchor Coal Zone

Like the Sego Sandstone, the name Corcoran is somewhat ambiguously applied and Young (1955) designated several marine sandstone and associated coal-bearing strata to the Corcoran sandstone member. Young (1955, p.190) states that its name is derived from exposures near the old Corcoran Mine north of Palisade. which Erdmann shows in sec. 27, T. 9 S., R. 100 W, and Young states that the Corcoran first appears in Big Salt Wash (between our section at Ruby Lee Reservoir and Coal Gulch, Fig. 4). We have no shoreface sandstone at Big Salt Wash but do have a continuous tidal unit that is most likely Young's Corcoran. The lowest prominent white capped sandstone at Mount Garfield is certainly the Corcoran of Young (see Young 1955, p. 191, discus-

The Cozzette Sandstone member is named for a prominent cliff-forming sandstone and overlying coastal plain and nearshore marine deposits up to the Rollins Sandstone at the Cozzette Mine (Young, 1955)(our Grasso Mine section, Figs 2 and 4). Correlation of individual sandstones of the Cozzette is complicated by incision and removal of the sandstone between Book Cliffs Mine and Layton Wash and has led to various correlation schemes (Gill and Hail, 1975; Young, 1983, Fig. 2). By and large, Young's correlations are excellent but do not show the

The Rollins Sandstone was first named by Lee (1909) for a prominent white sandstone at the top of the Mancos Shale in the Grand Mesa area southeast of Grand Junction. Lee (1912) miscorrelated the sandstone as he traced it westward into the Book Cliffs area; the 100 ft thick unnamed sandstone at the top of the Bowie Shale Member in Lee's Grand River section is actually the Rollins (Lee, 1912, Fig. 7, p. 79). This miscorrelation was corrected by Erdmann (1934, plate 4). We traced the Rollins into Layton Wash where it is replaced by sandstones of estuarine origin (Fig. 4). The Rollins is often discussed in conjunction with the overlying Cameo Coal Zone and they are thought to be genetically related. Erosion into the Rollins and fill by estuarine deposits suggests the



Depositional Environments (background color) Relative salinity (column color) Estuarine complex; estuarine Freshwater influence shoreface facies shown in orange Mt Garfield Fm (part) Upper Shoreface Brackish water influence Coastal Plain Rollins Sandstone Lower Shoreface & Offshore Normal marine Tongue of Mancos Shale Cozzette Ss Sulfur Canyon Bed Tongue of Mancos Shale Corcoran Ss 30-Sego Sandstone 10 Mancos Shale Fig. 4 - Cross section B-B' showing detailed correlations of coastal plain deposits, estuarine complexes, and shoreface deposits in the Colorado part of the Book Cliffs

Acknowledgments

Thanks to George Pemberton for identification of some trace fossils in the field and to John Van Wagoner and Peter McCabe for discussions on the Neslen Formation. We appreciate reviews from Chris Schenk, Margaret Ellis, and Katharine Varnes. Helle Mitgaard and Kat Beryk assisted in measuring sections in the field and Kat Beryk drafted numerous sections in the office. Sally Dyson is gratefully acknowledged for desktop publishing.

Trough or planar tabular Swaley cross-stratification cross-stratification Inclined strata with Hummocky cross-stratification 🖂 Bone current ripples Cross stratification with wave Gastropod Wave ripple rippled bounding surface Brackish-water bivalves Flaser beddin Bivalve fragments Wavy bedding Convoluted bedding PETERSON Bioturbated Double mud drapes or S S Burrows Streaky bedding carbonaceous drapes Paleocurrent direction Teredolites Erosional contact (ripples-open; x-beds-solid) 冷 Ophiomorpha Sharp contact Paleocurrent indicator U-shaped burrow Carbonaceous shale Roots Shark tooth Concretion Footprint ∨ ∨ Burned coal

Explanation

Stratigraphy and Depositional Environments of the Late Campanian Coal-bearing Neslen/Mount Garfield Formations, eastern Book Cliffs, Utah and Colorado

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North America Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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